For English proceed to page 4 and beyond

Βιομηχανική Καινοτομία και Αυτόνομα Τεχνολογικά Συστήματα· ερευνητικά θέματα (ή προπτυχιακές ή μεταπτυχιακές εργασίες) για το ακαδημαϊκό έτος 2023-2024

Σύνοψη

Το έγγραφο[1] περιέχει τέσσερις κατηγορίες ερευνητικών θεμάτων κατάλληλων για προπτυχιακές/μεταπτυχιακές διατριβές με θέμα τη Βιομηχανική Καινοτομία και Αυτόνομα Τεχνολογικό Σύστημα για το Τμήμα Μηχανικών Παραγωγής και Διοίκησης για το ακαδημαϊκό έτος 2023-2024. Οι κατηγορίες είναι οργανωμένες ως εξής:

1. Θέματα Βιομηχανικής Καινοτομίας και Αυτόνομα Τεχνολογικά Συστήματα
2. Θέματα για τη δυναμική και τον έλεγχο οχημάτων (VDC)
3. Θέματα με την ομάδα FStuc Formula Student
4. Θέματα με την ομάδα TUCer

Επιβλέπων: Διομήδης Κατζουράκης
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Τελευταία ενημέρωση: Nov 23, 2023
Κατάσταση εγγράφου: **Τελικό προς δημοσίευση**

Διευκρινίσεις

- Η Σύνοψη του παρόντος εγγράφου είναι γραμμένη στα ελληνικά και αγγλικά (δείτε Synopsis) όπως επίσης οι Τίτλοι ερευνητικών θεμάτων. Το υπόλοιπο κείμενο είναι γραμμένο μόνο στα αγγλικά. Τα θέματα μπορούν να δημιουργήσουν πολλές διαφορετικές προπτυχιακές ή μεταπτυχιακές διπλωματικές εργασίες. Οι μελλοντικοί ερευνητές-φοιτητές θα πρέπει να κοιτάξουν στο αγγλικό κείμενο για την πιο αναλυτική περιγραφή του θέματος
- Όλα τα θέματα στοχεύουν στην επίλυση ρεαλιστικών και τακτικών τεχνικών προβλημάτων, με στόχο να είναι είτε μια αυτοτελής έννοια (δηλ. Όρθιο γραφείο) ή να συμμετέχει ως θεμελιώδες τμήμα ενός μεγαλύτερου έργου ή στόχου (δηλαδή ανάπτυξη του οχήματος FStuc και συμμετοχή με επιτυχία στον διαγωνισμό του 2024)
- Τεχνικό ιδέα (Technical Concept). Κατόπιν συμφωνίας μεταξύ επιβλέπων και φοιτητή/ερευνητή, τα θέματα θα διαμορφωθούν ώστε να έχουν το κατάλληλο βάθος και πολυπλοκότητα. Ο επιβλέπων, πριν ξεκινήσει η εργασία, θα παράσχει στον μελλοντικό φοιτητή/ερευνητή ένα έγγραφο 4-6 σελίδων που θα περιγράφει την τεχνική ιδέα, την αρχική περιγραφή αρχιτεκτονικής και τις μηχανικές προσδοκίες ώστε να καταστεί δυνατή μια επιτυχημένη ερευνητική συνεργασία. Ο φοιτητής/ερευνητής εντός εύλογου χρονικού πλαισίου θα παράσχει ένα σύνολο στόχων μαζί με ένα χρονοδιάγραμμα για την παράδοση

[1] Αυτό το έγγραφο έχει υποστηριχθεί από την Τεχνητή Νοημοσύνη (AI) με https://chat.openai.com/ για κείμενο και https://creator.nightcafe.studio/studio για γραφικά

της α) υπόθεσης, β) ανασκόπησης βιβλιογραφίας, γ) μεθοδολογίας, δ) ανάπτυξης, ε) επαλήθευσης και επικύρωσης και ζ) συνεισφορών-συμπερασμάτων

- Βρείτε εδώ τις αναθέσεις διπλωματικών εργασιών
- Όλα τα θέματα απαριθμούν τον τελικό στόχο και υπονοούν ή αναφέρουν άμεσα τα απαιτούμενα σετ δεξιοτήτων
- Τα θέματα στο VDC εμπίπτουν στην ομπρέλα της Βιομηχανικής Καινοτομίας. Ωστόσο, έχουν διαφορετικό αρκτικόλεξο για να διευκολύνουν την ομαδοποίηση και την τάξη σε αυτό το έγγραφο
- Συνεποπτεία.Τα θέματα θα συνεποπτεύονται κατάλληλα με:
    - Καθηγητή Νίκο Τσουρβελούδη και/ή Επίκουρο Καθηγητή Λευτέρης Δοϊτσίδης από το Εργαστήριο Ευφυών Συστημάτων και Ρομποτικής,
    - Dr. Chronis Spanoudakis από το Εργαστήριο Εργαλειομηχανών,
    - Αναπλ. Prof. Γιώργος Αραμπατζής,
    - Dr. Savvas Piperidis υπεύθυνος για την Ομάδα TUCer
    - Καθηγητής Ιωάννης Νικολός, Διευθυντής του Εργαστήριο Στροβιλομηχανών & Ρευστοδυναμικής
    - Δυνητικά θα συμμετάσχουν περισσότεροι ακαδημαϊκοί και βιομηχανικοί επιβλέποντες κατά την ωρίμανση του θέματος και της ανάθεσης
- Ο τελικός στόχος και η προσδοκία από τον επιβλέποντα είναι η συμφωνημένη εκτέλεση της εργασίας ακολουθούμενη από την τεχνική έκθεση ή/και το πρωτότυπο HW ή SW που μπορεί να δημιουργήσει μια επιστημονική εργασία ή/και να αποτελέσει τη βάση για το Ph.D. έρευνα ή ένα προϊόν. Η αφοσίωση είναι απαραίτητη προϋπόθεση για την έναρξη, την πρόοδο και την επιτυχή ολοκλήρωση της συνεργασίας

Τίτλοι ερευνητικών θεμάτων

Industrial Innovation and Autonomous (I2A) Technological Systems; research projects (or undergraduate or postgraduate theses) for the academic year 2023-2024

Synopsis

This document[2] contains four categories of research projects appropriate for undergraduate/postgraduate theses on Industrial Innovation and Autonomous (I2A) Technological System for the Production, Engineering and Management for the academic year 2023-2024 (but not limited to). The categories are organized as follows:

1. Projects on Industrial Innovation and Autonomous Technological Systems
2. Projects on Vehicle Dynamics and Control (VDC)
3. Projects with FStuc Formula Student team
4. Projects with TUCer team

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Document status: **Final; for sharing**

Clarifications

- The Synopsis of this document is written in Greek (see Σύνοψη) and English. The rest of the text is only written in english. The research projects could create many different undergraduate or graduate theses (c.f. Research project titles). Future student-researchers should look to the English text (starting from page 6 and onwards) for a more detailed description on the projects
- All projects aim to solve pragmatic and tactical technical problems, targeted to be either a self contained concept (i.e. the Standing Desk) or be part an integral component of a greater project or goal (i.e. development of the FStuc vehicle and participating successfully in the 2024 competition)
- Technical Concept (TC): upon match and agreement between candidate and supervisor, the projects will be formulated to have the appropriate depth, complexity and span. The supervisor, prior to initiating the project, will provide to the future student/researcher a ~ 4-6 pager describing the technical concept, initial architecture description and engineering expectations to enable a successful research collaboration. The student/researcher within a reasonable timeframe will provide a set of goals along with a timeline for delivering the a) hypothesis, b) literature review, c) methodology, d) development, e) verification and validation and g) contributions-conclusions
- Find here the research project assignments

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[2] This project description doc has been aided from Artificial Intelligence (AI) with https://chat.openai.com/ for text and https://creator.nightcafe.studio/studio for graphics

- All projects list out the end-goal and imply or call out directly the skill sets needed
- Projects on VDC do fall under the Industrial Innovation (I2A) umbrella. However, they have a different acronym to facilitate grouping and order in this doc
- Co-supervision. The projects will be co-supervised appropriately with:
  - Professor Nikos Tsourveloudis and/or Assist. Professor Lefteris Doitsidis from the Intelligent Systems and Robotics Laboratory,
  - Dr. Chronis Spanoudakis from the Machine Tools Laboratory,
  - Assos. Prof. George Arampatzis,
  - Dr. Savvas Piperidis responsible for the TUCer team and
  - Professor Ioannis Nikolos, director of the Turbomachines & Fluid Dynamics Laboratory
  - It is probable that More industrial and academic supervisors could be involved upon project and assignment maturation
- End-goal and expectation from the supervisor is the agreed execution of the work followed by the technical report and/or HW or SW prototype that can generate a scientific paper and/or be the seed for Ph.D. research or a product. Dedication-devotion and urgency to work is a prerequisite to initiate, progress and complete successfully the collaboration

Research project titles

For English proceed to page 4 and beyond

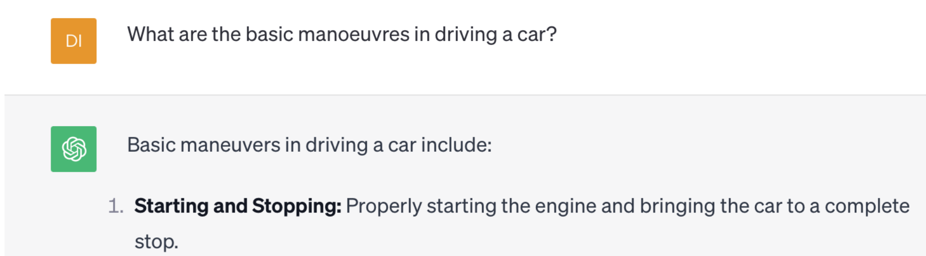
Projects on Industrial Innovation and Autonomous Technological Systems (I2A)

I2A1 Autonomous vehicles behavioral development using LLM (Large Language Models)[3]

A large language model, in the context of artificial intelligence and natural language processing, refers to a neural network-based model that has been trained on text data to process and generate human language. These models are known for their ability to perform a wide range of language-related tasks, including text generation, text completion, language translation, question answering, and more. Some well-known examples of large language models include ChatGPT (GPT-3 and GPT-4 OpenAI), BERT (Google), etc. each with its own architecture. These models have found applications in a wide range of fields, from chatbots and virtual assistants to content generation and more, thanks to their ability to understand and generate human language with a high degree of proficiency. Now, let's consider the application of driving a vehicle. We can decompose some of the core driving maneuvers as:

- **Driving in Traffic**: Maintaining a safe following distance, staying in your lane, and being aware of other vehicles.
- **Parking**: Parallel parking, perpendicular parking, and angle parking techniques.
- **Merging**: Safely merging onto highways and merging out of lanes or exit ramps.
- **Yielding Right of Way**: Knowing when to yield to other vehicles, pedestrians, and traffic signs or signals.
- **Intersections**: Navigating different types of intersections, including stop signs, yield signs, and traffic lights.
- **Etc**.

Referring to the "The general architecture of the computational model for agents" from J. Sifakis [I2A1Ref1] this project will explore the possibility of creating the "Decision and Goal Making" using a set of predefined behaviors extracted from LLM, assuming the existence of the rest of the functional blocks used in autonomous vehicles. The aim of the project is to apply the findings in simulation and aspirationally as-well-as a test bed autonomous scaled vehicle.



[I2A1Fig1] Answer of ChatGPT-3.5 in the question "What are the basic manoeuvres in driving a car?"

[I2A1Ref1] J Sifakis, Autonomous Systems--An Architectural Characterization, arXiv preprint arXiv:1811.10277, 2018•arxiv.org.

[3] With Dr. Doitisidis and Dr. Arampatzis

Skill Sets: Coding, autonomous vehicles fundamentals, controls

I2A2 Drive-by-wire system development for developing an autonomous/semi-autonomous electric vehicle[4]

A "drive-by-wire" system in an autonomous vehicle refers to a technology that replaces traditional mechanical linkages and controls with electronic systems. See I2A2Fig1 for the vehicle we target to transform to by-wire. A drive-by-wire system [I2A2Ref1] for an autonomous system will enable remote control and automation for the propulsion, braking, steering, gear shifting and parking brake systems by electronic sensors and actuators. It also allows for a test driver to take over control of the vehicle and/or maneuver it outside of the geofenced areas that the vehicle can operate autonomously. This project will start from system level requirements from control authority and performance and ability to take over [I2A2Ref2] and the necessary system states [I2A2Ref3] and will introduce the actuation and sensing mechanisms to enable successful drive-by-wire operation.

[I2A2Fig1] The target vehicle to use is the Eco car of Eco sun. https://ecocar.city/new-ecocar-city/

[I2A2Ref1] Diomidis Katzourakis, Huibert Mees, Paul W. Choin, “Steer-by-wire system with multiple steering actuators”, Patent number: 11370475, Date of Patent: June 28, 2022, Assignee: Apple Inc., Available: https://patents.google.com/patent/US11370475B1/
[I2A2Ref2] Diomidis Katzourakis, Ioannis N. Tzortzis, “Manual override,” Patent number:, Date of Patent: US10996673B1, May 4, 2021 Assignee: Apple Inc. Available: https://patents.google.com/patent/US10996673B1
[I2A2Ref3] Diomidis Katzourakis, Huibert Mees, Robert Cammarata, “Braking system control state transitions,” Patent number: 10,661,764, Date of Patent: February 28, 2018, Assignee: Apple Inc. Available: https://patents.google.com/patent/US10661764B1

Skill Sets: Coding, CAD, electrical and electronics engineering, (vehicle) dynamics, controls

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[4] With Dr. Tsourveloudis and Dr. Spanoudakis

I2A3 Exoskeleton concept design for individuals with limited mobility; concept design[5]

This project aims to design, develop a concept for an assistive exoskeleton system that provides mobility support for individuals with limited mobility (c.f. I2A3Fig1). The exoskeleton is intended to improve the quality of life and independence of users with limited mobility due. The system will be designed with a focus on true scalability (i.e. use of moderate cost components) user comfort, safety, and ease of use, and it will incorporate advanced technologies to enable enhanced mobility. Will use System engineering principles to derive goals and constraints (i.e. components, manufacturing and cost) and will propose a concept design with a human machine interface and performance requirements for components and actuators. End-goal is the CAD model of the exoskeleton, electrical architecture, HW and actuation architecture and block diagram of the control stack and human machine interface.

[I2A3Fig1] Exoskeleton for individuals with reduced mobility; image generated with AI

Skill Sets: CAD, electrical and electronics engineering, (vehicle) dynamics, controls

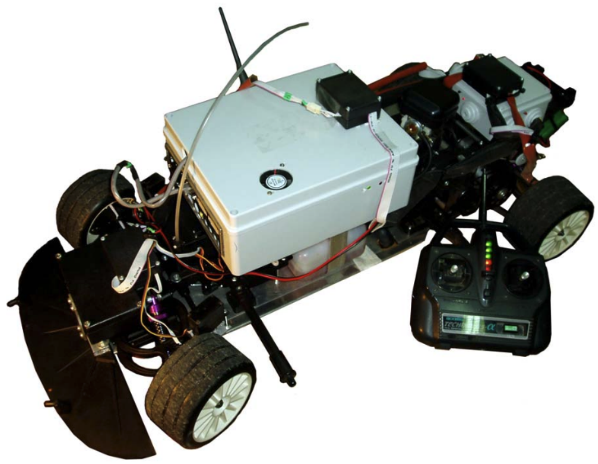
I2A4 Autonomous vehicle testbed development for the AutoKopeli challenge[6]

The AutoKopeli is an aspired Autonomous Scaled Vehicle Challenge that will be held in the Technical University of Crete in Greece. The idea is to create an autonomous scaled vehicle challenge that will navigate around the campus. The primary goal is to develop and test autonomous navigation systems that can navigate a predefined course while overcoming various

[5] With Dr. Spanoudakis

[6] With Dr. Spanoudakis and Dr. Tsourveloudis

obstacles and challenges. The project will focus on the concept test vehicle that will be used as common platform architecture for all the competitors. Thus it will decompose the concept following the goals to requirements cascaded from one the next starting from 1) AutoKopeli[7] challenge goals, 2) time and cost constraints, 3) TestBed form factor, 4) scalability and upgrading, 5) Sensing HW, 6) Autonomy compute, 7) embedded HW/SW, 8) CAD design, 9) integration of HW components, 10) integration of SW components. See as example [2A4Fig1] or refer here for more modern examples.



[I2A4Fig1] Scaled testbed from D. Katzourakis, Scaled Testbed for Automotive Experiments, 2008. Available: https://dias.library.tuc.gr/view/13420

Skill Sets: Coding, autonomous vehicles fundamentals, CAD, electrical and electronics engineering, (vehicle) dynamics, controls

I2A5 Autonomous shuttle service for the campus of the Technical University of Crete[8]

The Autonomous Shuttle service for the Technical University of Crete (c.f. I2A5Fig1) is a step towards a convenient, eco-friendly, and cost-effective public transportation option for the dense urban environment aiming to transfer the knowledge and lessons learned within I2A1, I2A2 and I2A4. The project will focus on a concept description of an urban geofenced area, where public means of transportation will co-exist with pedestrian zones, reduced footprint means of mobility (i.e. bicycles, electric scooters) and will operate in the principle of fixed routes but with possibility to do path augmentation so as to manage obstructions, construction zones etc. The end-goal is a platform and sensing and compute architecture needed to enable a viable campus shuttle service including offboard and infrastructure system requirements. It is expected to demonstrate in a simulation environment instances of operation and execution of behaviors as described in I2A1.

[7] The AutoKopeli challenge is our TUC aspired Autonomous Scaled Vehicle Challenge targeted for 2025. Dr. Chronis Spanoudakis is the incubator of the idea

[8] With Dr. Tsourveloudis and Dr. Doitsidis. The Autonomous shuttle service for the campus of TUC is an aspired project aiming to start testing in 2025 as a cross functional effort among multiple departments of TUC as-well-as established research and industrial partners within and outside Greece

[I2A5Fig1] Autonomous shuttle service for the campus of the Technical University within the campus Olive trees; image generated with AI

Skill Sets: Autonomous vehicles fundamentals, CAD, electrical and electronics engineering

I2A6 Standing desk design and control for improved productivity and physical conditioning; concept design[9]

This project will design and implement a "Smart Standing Desk" aimed at improving both productivity and physical well-being for office workers and individuals with sedentary lifestyles. The project will involve the design, development, and evaluation of an adjustable standing desk integrated with sensors and a control system to encourage regular standing and movement while working. This innovative approach seeks to enhance work efficiency and overall health. End-goal will be a working prototype including a simple ergonomics survey related to work performance, user comfort, and posture improvement.

[9] With Dr. Spanoudakis

[I2A6Fig1] Standing desk on top of a fixed desk; image generated with AI

Skill Sets: CAD, electrical and electronics engineering, vehicle dynamics, controls

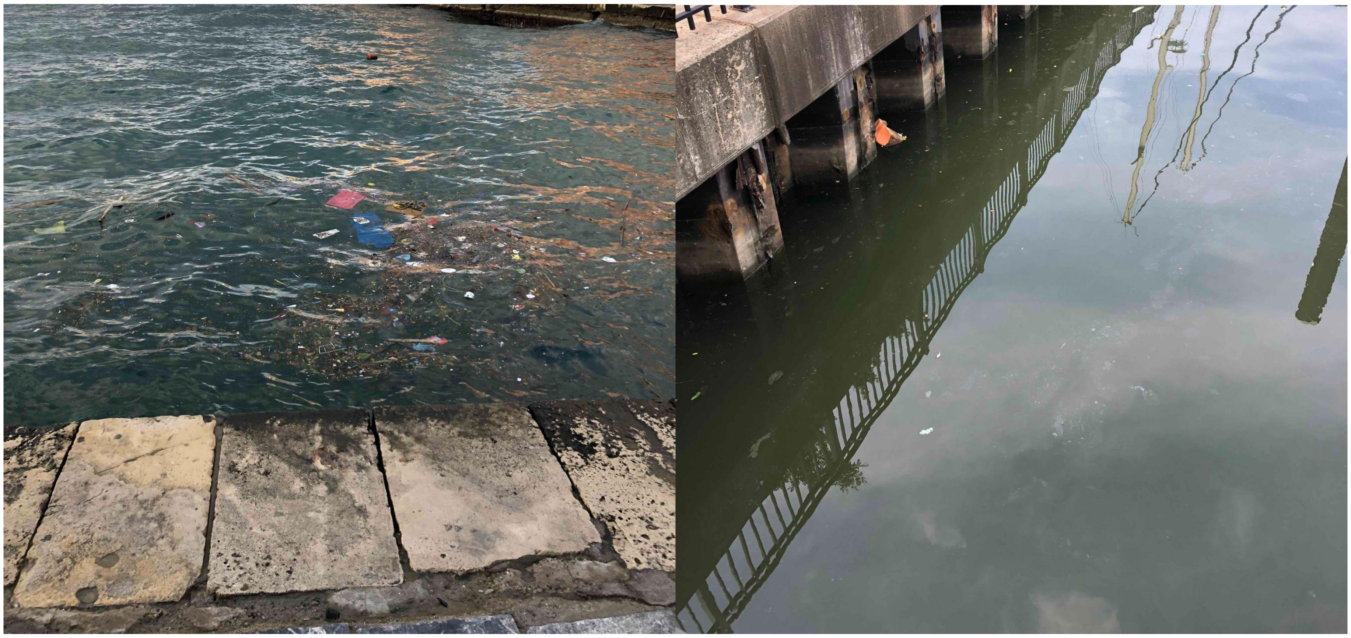
Thesis assigned to: Georgios Gatos on 2023-11-07

I2A7 Semi-autonomous/autonomous trash collecting water vessel within a Geofenced Environment; concept design[10]

Thrash floating on harbor water is not a rare sight. Quite often it happens due to drift of thrash from the sea (c.f. I2A7Fig1) and possibly it has nothing to do with the actual environment that the thrash accumulates. Still, besides the social economic impact and the visual impairment, there is a biological downside for the environment that can be addressed with present engineering means. With the current leaps in technology in both sensing and with the help of AI, it is possible to design a semi-autonomous/autonomous trash collecting water vessel within a Geofenced Environment (i.e. a harbor) that can navigate efficiently through harbors and coastal areas. This project will create a thrash water thrash cleaning vessel that can be either semi-autonomous or fully autonomous designed to clean up and remove debris and litter from the waters in harbors and coastal areas. The project will create a concept design that will use System engineering principles to propose a solution subject to cost and scalability constraints. It will decompose the problem from the cleaning goals to set of system level requirements in terms of the vessel form factor and its propulsion architecture, the collection mechanism, the HW compute compute and the overall fault tolerant and failsafe functionality (i.e. redundancy in core domains so that platform can always be navigated back to base), the sensing and localisation modalities and of course the

[10] With Dr. Tsourveloudis and Dr. Arampatzis

thrash collection and trash disposal and docking mechanisms. End-goal is the CAD model of the platform, electrical architecture, HW and actuation architecture and block diagram of the autonomy stack and human machine interface.



[I2A7Fig1] Tash drift in harbors; images from the supervisor

[I2A7Fig2] Trash collecting unmanned water vessel; image generated with AI

Skill Sets: Autonomous vehicles fundamentals, CAD, electrical and electronics engineering, (vehicle) dynamics, controls

I2A8 Semi-Autonomous/Autonomous litter collecting vehicle for beach usage; concept design[11]

Thrash on the beach becomes more or less inevitable especially in principal tourist months. A beach sand-cleaning robot can help maintain the environmental health of the beach by removing litter and debris that can pose risks to wildlife (i.e. nesting turtles), beachgoers (i.e. broken glass), and the overall attractiveness of the shoreline. This project will design a concept of a robot or contraption of the appropriate free form that can clean and keep the beaches free from various forms of litter and debris from. I2AFig1 conceptualizes a robot that can navigate on a sandy beach and pick-up litter. This project is similar to the approach of I2A7 but with different application. It will create a concept design that will use System engineering principles to propose a solution subject to cost and scalability constraints. It will decompose the problem from the cleaning goals and failsafe mechanisms to set of system level requirements in terms of the vehicle form factor and its propulsion architecture, the HW compute, the sensing and localisation modalities and of course the thrash collection and litter disposal and docking mechanisms. End-goal is the CAD model of the platform, electrical architecture, HW and actuation architecture and block diagram of the autonomy stack and human machine interface. The trash collection mechanism could be a conveyor belt or rake system that scoops up trash, including cigarette butts, plastic bottles, wrappers, and other lightweight debris, from the surface of the sand (c.f. example and here).

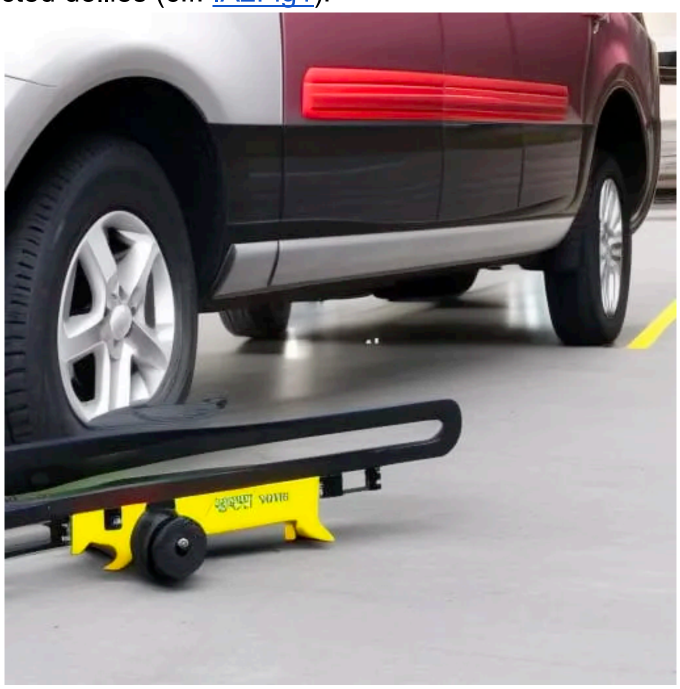
[I2A8Fig1] Beach litter cleaning robot; image generated with AI

Skill Sets: Autonomous vehicles fundamentals, CAD, electrical and electronics engineering, (vehicle) dynamics, controls

[11] With Dr. Tsourveloudis and Dr. Arampatzis

I2A9 Semi-Autonomous/Autonomous parking dolly; concept design[12]

Parking lots or privately owned and controlled parking spaces are often poorly utilized. They have been designed subject to the kinematic constraints of manually driven vehicles and they budget for quite some space to maneuver the vehicle around. Additionally quite often have too high approach or departure angles and or very steep inclinations, yielding them unusable. Additionally, cars cannot get stacked longitudinally because it would require the presence of the owner to drive the vehicle. Overall, the actual space to park vehicles might be there, but the utility is not. This project can be combined to interface with the idea of parking sharing too that is being worked on with Dr. Arampatzis' research team. This project is similar to the approach of I2A7 and I2A8 but with applications to facilitate parking via Semi-Autonomous/Autonomous parking dolly. It will create a concept design that will use System engineering principles to propose a solution subject to cost and scalability constraints. It will decompose the problem from the parking goals and failsafe mechanisms to set of system level requirements in terms of the vehicle form factor and its propulsion architecture, the HW compute, the sensing and localisation modalities and of course the parked vehicle handling and lifting mechanism, including its own docking and charging mechanisms. End-goal is the CAD model of the platform, electrical architecture, HW and actuation architecture and block diagram of the autonomy stack and human machine interface. The parking dolly mechanism could be inspired by wheel lift dollies or be something more exotic within independent or connected dollies (c.f. IA2Fig1).



[I2A9Fig1] Creation: car wheel lift dolly; image generated with AI

Skill Sets: Autonomous vehicles fundamentals, CAD, electrical and electronics engineering, (vehicle) dynamics, controls

[12] With Dr. Arampatzis and Dr. Spanoudakis

I2A10 Distributed environmental sensing station for prediction and monitoring, using machine learning and artificial intelligence[13]

This project will architect a modular and cost effective environmental sensing station that will use low cost sensing modalities and machine learning to monitor and predict environmental information which can be used from agriculture (from irrigation control to statistical information) to emergency prediction and mitigation (i.e. early communication of impending catastrophes such as wildfires and floods). The idea is to create a station network powered by renewable energy sources (i.e. solar or wind) and via the appropriate network configuration its “simple node” will communicate and broadcast incoming information with its neighboring nodes up to the point that reaches a node that has cellular connectivity, a “super node.” Individual node will carry its unique id in terms of location and the system will be configured appropriately to broadcast information accordingly so as to maintain the appropriate system bandwidth and unnecessary back-talk. End-goal of this project is:

- a) architect and propose the system’s components from electrical engineering perspective and will simulate a mockup of this distributed network hub and
- b) create an actual application for either coastline (local sea weather for wind and waves) or inland (fire and humidity estimation)

Skill Sets: Coding, electrical and electronics engineering, networks

[13] Projects will be co-supervised with academic and possibly industrial collaborators beyond PEM

Projects on Vehicle Dynamics and Control (VDC)[14]

VDC1 State estimation using machine learning (ML)

State estimation involves the process of estimating the current or past state of a dynamic system based on a series of observations or measurements, even when the exact state of the system is not directly observable or known. Body reference speed and body side slip angle [VDC1Ref1] are the two most common states in the vehicle dynamics used for ABS and ESC correspondingly, with roll angle and friction coefficient mu being the next most interesting. This project will look into combining a) common state estimation techniques including Kalman and extended Kalman filtering that use the available measurements and the system model to update and refine state estimates over time with b) machine learned models that help to estimate and/or act as a source of redundancy in the sensing (i.e. yaw rate estimation using neural networks [VDC1Ref2]) or do the state estimation. The idea is to create a trusted monitor with low performance using common techniques augmented with a high performant ML based state estimation that will enable it to meet functional safety requirements of the ISO-26262. End-goal of this project to architect and create such a model of states using vehicle dynamics models and simulated or real measurements.

[VDC1Ref1] Diomidis Katzourakis, Huibert Mees, Christopher D. Gadda, Stefan Solyom, Johannes A. Huennekens, “Vehicle Stability Control,” Patent number: 10,384,672, Date of Patent: August 20, 2019, Assignee: Apple Inc. Available: https://patents.google.com/patent/US10384672B1

[VDC1Ref2] D. Katzourakis, Y. Papaefstathiou, M. Lagoudakis., “An Open-Source Scaled Automobile Platform for Fault -Tolerant Electronic Stability Control,” IEEE Transactions on Instrumentation and Measurement, vol. 59, no. 9, pp. 2303-2314, 2010.

Skill Sets: Coding, (vehicle) dynamics, controls

VDC2 Vehicle ride control in the era of ADAS and autonomous vehicles

Modern vehicles are equipped with an abundance of sensing modalities, from inertial measurements to cameras and lidars. This project aims to propose of an architecture that combines innovative active suspension mechanisms (i.e. VDC2Ref1) with the sensing modalities mentioned above that can be found in L2+ SAE vehicles. End-goal is the proposal of concepts and the implementation in simulation of a vehicle ride control algorithm assuming the presence of the active suspension and the perception system that can scan the road real-time, as-well-as use a priori information.

[14] Projects will be co-supervised with academic and possibly industrial collaborators beyond PEM

[VDC2Fig1] Road scanning with laser; image generated with AI

[VDC2Ref1] Diomidis Katzourakis, Christopher L. Porritt, Johannes A. Huennekens, Huibert Mees, Paul J. Keas, “Active suspension system with energy storage device,” Grant Number: US10814690, Grant Date: October 27, 2020, Assignee: Apple Inc. Available: https://patents.google.com/patent/US10814690B1

Skill Sets: Autonomous vehicles fundamentals, electrical and electronics engineering, (vehicle) dynamics, controls

VDC3 Over actuated chassis controls using optimization techniques and artificial intelligence

Imagine a platform with drive-by-wire (i.e. For example this Porsche 718 Cayman GT4 https://www.pmeautoconversions.com.au/news/112-paravan-racing-nurburgring). Such an over actuated platform (c.f. VDC3Ref2) has more actuation mechanisms than a normal human expert driver can control. This project will explore an architecture that combines common optimization techniques and artificial intelligence and will implement a novel prototype control scheme that exploits all control modalites so as to allow full limit handling capabilities and maneuverability of an over actuated chassis (i.e. VDC3Ref1 that uses the vehicle’s layout as constraints to the optimization problem). End-goal is a simulating such a controller and displaying its potentials.

[VDC3Ref1] D. Tavernini, M. Massaro, Matteo, E. Velenis, D. Katzourakis, R. Lot, “Minimum Time Cornering: The Effect of Road Surface and Car Transmission Layout,” Vehicle System Dynamics, vol. 51, no. 10, 2013.

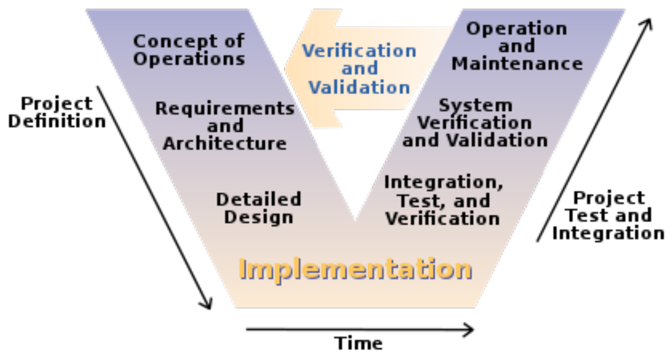
[VDC3Ref2] Diomidis Katzourakis, Huibert Mees, Paul W. Choin, “Steer-by-wire system with multiple steering actuators”, Patent number: 11370475, Date of Patent: June 28, 2022, Assignee: Apple Inc., Available: https://patents.google.com/patent/US11370475B1

Skill Sets: Autonomous vehicles fundamentals, electrical and electronics engineering, (vehicle) dynamics, controls

Projects with FStuc (Formula Student Technical University of Crete) team

FST1 Systems Engineering; From project goals to Validation and Verification for the 2023 FStuc vehicle[15]

The 2023 FStuc vehicle constitutes a milestone for the FStuc; it was the first ground up vehicle designed by the 2022-2023 team with Ernesto Sigalas, Sergios Stergiou and the rest of the dedicated team members under the supervision of Professor Ioannis Nikolos. The 2023 FStuc should become a reliable platform that can operate seamlessly to aid the development of the 2024 and future vehicles. End-goal of this project is the derivation of core goals to system level requirements that will allow for a comprehensive validation and verification of the platform. The project responsible should create the functional decomposition and verification methods that meet these functional requirements, in combination with the rest of the team members. See FST1Fig1 model and refer to https://en.wikipedia.org/wiki/V-model.



[FST1Fig1] System engineering V-model; image from https://en.wikipedia.org/wiki/V-model

Skill Sets: CAD, electrical and electronics engineering, (vehicle) dynamics, controls

FST2 Electrical and electronic system upgrade for the 2023 FStuc vehicle

This project proposal outlines the expansion and enhancement of the electrical and electronic systems for the 2023 FStuc car. This project will analyze the previous design and lessons learned, aiming to improve safety, performance, reliability and data acquisition capabilities, shall propose a comprehensive upgrade of the vehicle's electrical and electronic components. It will rely on Systems engineering techniques of target setting to functional requirements decomposition to verification and validation of the design. End-goal is a fully verified and validated electrical and electronic system for the 2023 FStuc vehicle that will allow it to operate seamlessly reliably and will serve as a great test bed for data acquisition and development of the next vehicle.

[15] With Dr. Nikolos

[FST2Fig1] Electrical wire spaghetti; image generated with AI

Skill Sets: CAD, electrical and electronics engineering, (vehicle) dynamics, controls

FST3 Single cylinder Internal combustion engine tuning subject to air induction limitations and transmission layout using optimization techniques

The formula student competition requires a 20mm air restriction in the intake of internal combustion engines. The intake design should allow the engine to operate reliably subject to the airflow constraints. This project will utilize the improved air intake manifold redesign planned under professor Nikolos and will explore how to best adjust the internal combustion engineer (ICE) (in simulation) the fuel delivery, air-fuel ratios and ignition timing so as to get the maximum performance out of the engine, as-well-as a provide a reference for remapping the ECU for the 2023 and possibly the 2024 vehicle. End-goal of this project is the formulation of an optimization problem that its output can be applied to both the 2023 and 2024 vehicle.

[FST3Fig1] Car engine; image generated with AI

Skill Sets: Coding, (Vehicle) dynamics, controls

FST4 Systems Engineering; Functional requirements development and decomposition for the 2024 FStuc vehicle

This project builds up upon FST1 and further decomposes the Formula student rules and constraints to a set of actionable System level requirements (i.e. the load cases the vehicle has to withstand to remain competitive), that will be further decomposed to sub-system (i.e. front suspension assembly) to component requirements (i.e. sizing of the components to withstand the loads system loads). This will provide a set of specifications that if verified and validated should meet the top level goals and meet the competition regulations. See FST1Fig1 model and refer to https://en.wikipedia.org/wiki/V-model. End-goal is a compass for development that will add leadership to meet the goals, which is to make a competitive and at the edge platform, as-well-as traceability and pedigree history on the design.

Skill Sets: CAD, electrical and electronics engineering, (vehicle) dynamics, controls

FST5 Vehicle Dynamics Attributes Development for the 2024 FStuc vehicle

Vehicle dynamics attributes refer to the various characteristics and behaviors of a vehicle as it moves, turns, accelerates, brakes, and responds to driver inputs and external forces. These attributes are crucial in understanding and improving the performance, safety, and handling of a vehicle. This project builds upon FST1 and FST4 to specify the 2024 formula student vehicle dynamics attributes; these will be around steering response, acceleration and braking and cornering stability-handling. The attributes will serve as a compass to the rest of the design teams so as to set the appropriate design goals. For example, the understeer gradient of the vehicle can be controlled via multiple means of the suspension design including roll and bumps-steer, as-well-as front-rear axle roll stiffness etc. End-goal of this project is the core set of Vehicle Dynamics Attributes targets, subject to the design goals for the team.

[FST5Ref1] S. Angelis, M. Tidlund, A. Leledakis, M. Lidberg, M. Nybacka, D. Katzourakis, “Optimal Steering for Double-Lane Change Entry Speed Maximization,” in the proc. of the 12th International Symposium on Advanced Vehicle Control 2014, AVEC14, Tokyo, Japan, 2014.
[FST5Ref2] Ljungberg, M., Nybacka, M., Gómez, G. G., and Katzourakis, D. (2015). Electric power assist steering system parameterization and optimisation employing computer-aided engineering. SAE World Congress, April 21-23, Detroit, USA.

Skill Sets: Coding, (Vehicle) dynamics, controls

FST6 Front and rear suspension attribute development that meet the 2024 FStuc vehicle dynamics behavior

This project aims to specify the front and rear suspension attributes subject to the design goals and system level requirements from FST4 and FST5 (i.e. how to design a suspension for steer-by-wire vehicle FST6Ref1). These attributes would be bump/roll steer, camber gain, camber/kingpin inclination angles etc. that will meet the goals of the vehicle dynamics attributes FST5 .

[FST6Fig1] Suspension design of a formula student; image generated with AI. I hope via optimization techniques to do better than that!

[FST6Ref1] Diomidis Katzourakis, Huibert Mees, Johannes A. Huennekens, Robin A. Auckland, Paul W. Choin, “ Suspension architecture for steer-by-wire vehicle,” Patent number: 10,351,162,

Date of Patent: July 16, 2019, Assignee: Apple Inc. Available: https://patents.google.com/patent/US10351162B1

Skill Sets: CAD, Coding, (Vehicle) dynamics, controls

FST7 Vehicle mechanical design with focus on the front and rear suspension that meet the 2024 FStuc vehicle dynamics attributes

This project aims to drive the vehicle mechanical design with focus (but not limited to) on the front and rear suspension (c.f. FST7Fig1) subject to the design goals and system level requirements from FST4 and FST5 (i.e. how to design a suspension for steer-by-wire vehicle FST6Ref1). These attributes would be bump/roll steer, camber gain, camber/kingpin inclination angles etc. (c.f. FST7Ref2) that will meet the goals of the vehicle dynamics attributes FST5. The thesis will derive the hardpoints and design the components that meet the attributes as goals and expected suspension loads. The loads will be derived from instrumenting and testing the 2023 FStuc vehicle using accelerometers and strain gauges (thus it includes instrumentation, measurement, analysis and coding). Refer to FST7Ref3 and FST7Ref4 as reference for this work. Ideally, the components will be benchmarked against suspension components designed using generative AI and will assess optimal vs feasible (due to manufacturing). End goal is: a) deliver the front and rear suspension components in time for the 2024 FStuc vehicle, designed using Systems engineering principles and b) a technical report that describes the methodology aiming to be published. It is expected that the assigned student will collaborate with other team members both generating the attributes (i.e. FST4/FST5), as-well-as designing the parts (the suspension) and supervise their work so that it all integrates together. This thesis could include (but not requested) the design of the intake manifold (c.f. FST3), following the similar scientific methodology.

[FST7Fig1] Suspension design of a formula student; image generated with AI

[FST7Ref1] Diomidis Katzourakis, Huibert Mees, Johannes A. Huennekens, Robin A. Auckland, Paul W. Choin, " Suspension architecture for steer-by-wire vehicle," Patent number: 10,351,162, Date of Patent: July 16, 2019, Assignee: Apple Inc. Available: https://patents.google.com/patent/US10351162B1
[FST7Ref2] S. Angelis, A. Johnsson, M. Klomp, R. Hansson, D. Katzourakis, "Virtual Brake Software Release," 24th International Symposium on Dynamics of Vehicles on Roads and Tracks, Graz, Austria, 2015.
[FST7Ref3] Y. Samant Saurabh, Santosh Kumar, Kaushal Kamal Jain, Sudhanshu Kumar Behera, Dhiraj Gandhi, Sivapuram Raghavendra, Karuna Kalita, Design of Suspension System for Formula Student Race Car, Procedia Engineering, Volume 144, 2016, Pages 1138-1149, ISSN 1877-7058, https://doi.org/10.1016/j.proeng.2016.05.081
[FST7Ref4] Wheatley, G. On the design of racing car suspension. *Int J Interact Des Manuf* **14**, 1003–1013 (2020). https://doi.org/10.1007/s12008-020-00668-7

Skill Sets: CAD, Coding, (Vehicle) dynamics, controls

FST8 Battery pack and Battery management system development

Design, engineer and architect a scalable 44.4 V Lithium battery pack, together with a battery management for charging and discharging and balancing. The scalability aspect has to do with reusability for an EV that could be stacked up to 577.2 volts and can be used synergistically with the FStuc EV development.

Skill Sets: Coding, electrical and electronics engineering

FST9 3-phase induction motor propulsion and regeneration control

Integrate of the shelf components to create an EV powertrain system that can do propulsion and regeneration control. The system will be powered with the 44.4 V from above and will be tested on the bench. This will serve as a step with the FStuc EV development.

Skill Sets: Coding, electrical and electronics engineering, controls

Projects with the TUCer (Technical University of Crete, Eco Marathon) team[16]

TUCer1 Optimal speed management for minimization of energy consumption for the TUCer vehicle

The TUCer hydrogen vehicle uses hydrogen gas as a fuel source to generate electricity through a chemical reaction in fuel cells, which powers electric motors to drive the vehicle. Fuel cells are generally between 40 and 60% energy efficient [TUCer1Ref1] and their efficiency depends on the fuel cell type design (c.f. WikiPedia Fuel_cell). Electric motors have a range of speeds and loads at which they are most efficient, while vehicle's exhibit themselves parasitic losses that end up being function of the traveling speed (i.e. air drag) and/or non speed dependent losses such-as losses in the driveline or the tire rolling resistance (partially speed depended). This project will model the powertrain and vehicle and will identify the optimal operating point for maximum range. End-goal is to provide the speed setpoints for maximum energy efficiency.

[TUCer1Ref1] "Comparison of Fuel Cell Technologies" Archived 1 March 2013 at the Wayback Machine. U.S. Department of Energy, Energy Efficiency and Fuel Cell Technologies Program, February 2011, accessed 4 August 2011

Skill Sets: Coding, electrical and electronics engineering, (vehicle) dynamics, controls

[16] With Dr. Pipperidis